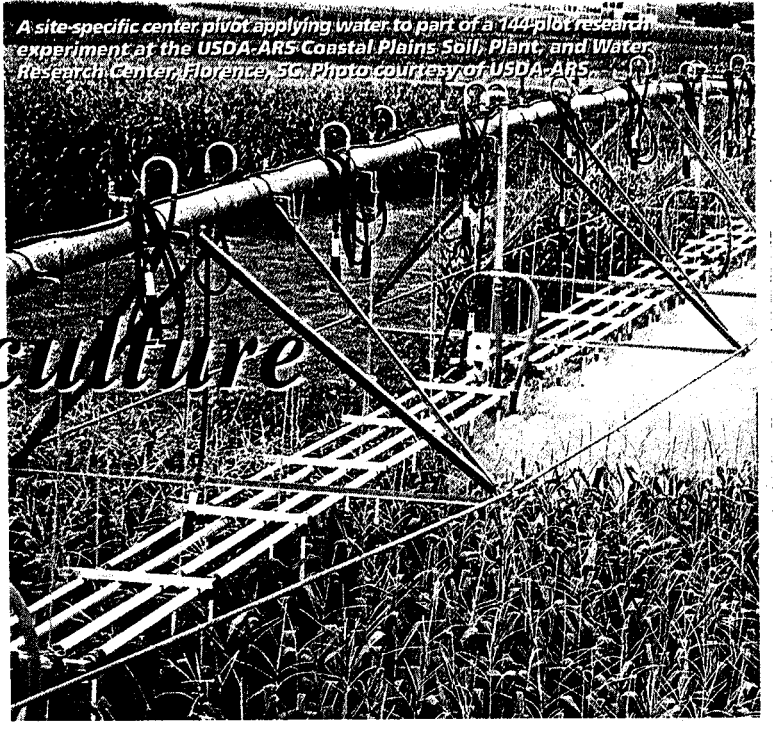
Venturing into Precision Agriculture

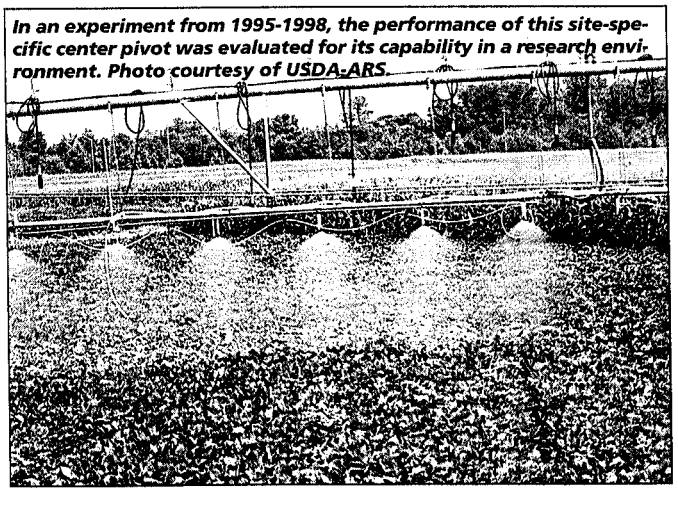

A site-specific center pivot applying water to part of a 144-plot research experiment at the USDA-ARS Coastal Plains Soil, Plant, and Water Research Center, Florence, SC. Photo courtesy of USDA-ARS.

By John Sadler, Robert Evans, Gerald Buchleiter, Bradley King and Carl Camp

In the 1990s, precision (or site-specific) agriculture emerged as a popular topic on both the production and research fronts. The first commercialized variable-rate applicator was for dry granular fertilizer, and much of the early work concentrated on variable-rate application of nutrients. Interest also spread to herbicides and pesticide applications, according to weed and pest pressures. Now, irrigation has become the latest crop input with possibilities for variable rate application. For much of the US, irrigation is the predominant managed application, and for other regions, it may be more important than commonly recognized.

Research teams represented by the authors developed variable-rate irrigation machines at four research centers in the US. These were located at the USDA-ARS in Ft. Collins, CO (Buchleiter and colleagues), the University of Idaho (King and colleagues), at the USDA-ARS in Florence, SC (Sadler and Camp), and at Washington State University (Evans and colleagues). All groups modified commercial center pivot or lateral move systems, but developed new elements in irrigation design and new management systems for this type of site-specific irrigation.

The design phase, for example, had to allow for variable-rate application in different segments along the machine. This required additional plumbing, control valves, and either more or different sprinklers. As with any increase in machine complexity, additional equipment meant more places where failure could occur. Thus, maintenance plays a bigger role with variable rate than with conventional irrigation equipment. And, finally, if site-specific irrigation is to be worthwhile, then management of different areas under the machine must be custom-tailored. Many issues must be considered before undertaking site-specific irrigation.


In an experiment from 1995-1998, the performance of this site-specific center pivot was evaluated for its capability in a research environment. Photo courtesy of USDA-ARS.

Why Consider Variable Rate Technology (VRT) ?

With these engineering challenges alone, you might wonder why anyone would venture into the realm of site-specific irrigation. For many, if not most fields, it is clear that some areas develop water stress before others. It seems natural to want a machine to apply enough water in those spots without over-watering the rest. However, economic incentives to save water may appear insufficient to justify spending more for these machines.

Diseases or rank growth, aggravated by unnecessary watering in low or naturally wet areas, may require costly chemicals for control or cause yield losses. During drought, or under conditions of limited water supply or allocation, applying water to only certain parts of a field may provide other incentives. Some regional regulations restrict application of water and nutrients on areas such as rock outcrops, standing water, roads, canals, or other bodies of water. Under these conditions, VRT irrigation adds incentives and may be quite appropriate. Center pivots that cannot make a full rotation because of unproductive or poorly drained soils on the field may benefit as well.

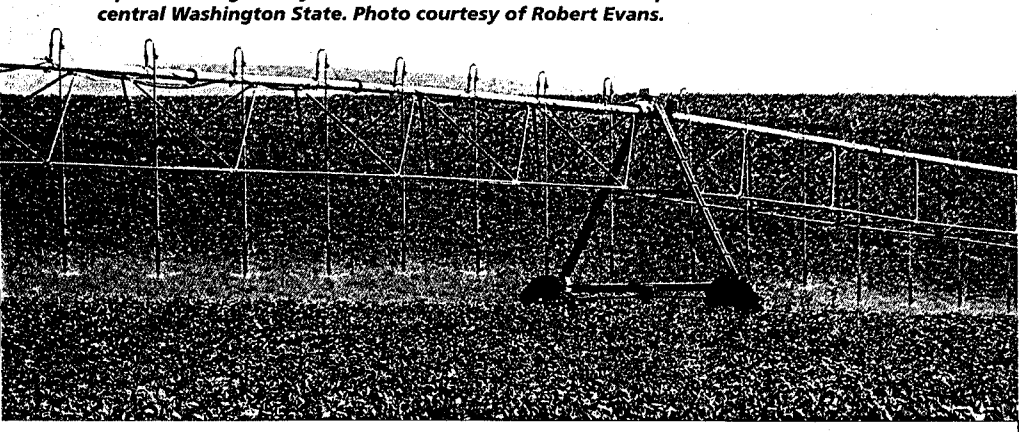
Researchers love VRT machines. In situations where treatment differences are imposed, they are ideal. Where several smaller fields of crops are located under a pivot, such as with fresh market vegetables and in nurseries, site-specific capabilities may be particularly beneficial.

While it is not possible to state beforehand the conditions under which site-specific irrigation is recommended, we wanted to share several design elements that we have found necessary to understand in VRT irrigation.

Variable-Rate Sprinklers

The core technology of a site-specific irrigation machine is the device that can apply one amount of water in one area and a different amount in another. For solid-set systems, such as in some nurseries, this capability may simply include varying the time a sprinkler is running. Zones are

A precision irrigation system installed on a commercial center pivot in south central Washington State. Photo courtesy of Robert Evans.



defined according to the needs of the plants in addition to the capacity of the water supply. For moving systems, the traditional method to vary the depth of application is to vary the speed of the machine. This creates wedge-shaped areas for center pivots and rectangular areas for lateral move systems. However, if the size of the machine (the application boom) exceeds the size of the desired management zone as defined by crop, soil, or other variation, then individual sections of the machine must be controlled separately to achieve site-specific irrigation. We accomplished this using one of three methods. Each one required valves distributed along the machine to control individual sections or sprinklers.

Pulsed methods, such as those tested in Ft. Collins and Washington, switch sprinklers on and off for a fraction of a base time period (such as 40 seconds on and 20 seconds off each minute to apply 67% of the full irrigation depth). This time-proportional control allows for fine-tuning of the application depth from 0% to 100%. This approach can be done for individual sprinklers or for banks of sprinklers on a separate manifold attached to the machine. Step-wise methods use multiple manifolds, each with nozzles that apply different amounts. In Idaho, two manifolds were used with nozzles sized 33% and 67% of full flow. This setup allowed depths of 0% for neither nozzle, 33% for the smaller only, 67% for the larger only, and 100% for both. The South Carolina design used 3 manifolds, and achieved 0% to 100% in increments of 14 percent.

A third technique, developed in Idaho, combines both theories into one sprinkler. A nozzle sized at 100% is fitted with a small stainless steel pin that is inserted or removed from the orifice with a solenoid. When inserted, the flow is 40% of full flow. By cycling the pin in or out for fractions of a base time period, near-continuous control between 40% and 100% can be achieved. A separate solenoid valve is used to completely shut off the individual sprinklers.

Controllers

Most commercial irrigation machines are delivered with a built-in computerized control panel that

allows programmed operation according to the position of the machine (thus controlling in one dimension). However, subdividing the machine into sections along the boom (to get a second dimension) requires some additional control. In each of the designs we have tried, this has taken the form of standard industrial programmable logic controllers (PLCs) with some communication link between the machine's control panel and the add-on PLC. Different implementations have used one of two different methods to control the individual valves. One uses wires to control each valve; the other uses addressable devices on a bus system.

The Pumping System

With sections of a machine operating at different flow rates, the aggregate flow rate of the machine can vary considerably. Depending on the method of supplying water to the variable-rate irrigation machine, special pumping capabilities may be needed to provide the proper operating pressure at all possible flow scenarios. For systems in western states, where the lowest likely flow is still 75% of full application, flow rates may operate over a narrow enough range that standard centrifugal pumps can handle it. For systems in humid areas, or for nursery, research, or other systems with wide potential variation in flow rate, two variable-flow water supply methods have been implemented. The first uses staged pumps in combinations according to the desired flow rate, usually with pressure control and high-pressure bypass to a reservoir. The second, which needs no reservoir, uses a variable-speed pump. Each system has cost and capability advantages and disadvantages. The inefficiency (energy costs) associated with pumping excess water back into a reservoir may be partially offset with a variable-speed pump.

Management Recommendations

From the experiences of the authors, the hardware necessary to achieve site-specific irrigation can be designed and implemented. As with other areas of variable rate technology, the equipment is the easy part. Once you have the machine, you still must tell it what to do. In most cases, this information may not be available. Variable-rate management of water has received less research attention than VRT management of nutrients or pesticides. Thus, one of the primary functions of these research machines is to develop management guidelines and production functions for combinations of crops, soils, and weather. It is unlikely that specific guidelines can be developed for all combinations of economic, agronomic, labor, environmental, and regulatory constraints that an individual irrigation manager encounters. We hope to develop general guidelines so that managers, consultants, and extension personnel can work with irrigators who choose to use variable rate irrigation to solve their water distribution problems.

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